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Citation for published version:
Corneli, J, Holland, S, Pease, A, Mulholland, P, Murray-Rust, D, Scaltsas, D & Smaill, A 2019, Patterns of Design. in *23rd European Conference on Pattern Languages of Programs (EuroPLoP '18).*, 22, ACM, Irsee, Germany, pp. 22:1-22:11, 23rd European Conference on Pattern Languages of Programs, Kloster Irsee, Bavaria, Germany, 4/07/18. https://doi.org/10.1145/3282308.3282331

Digital Object Identifier (DOI):
10.1145/3282308.3282331

Link:
Link to publication record in Edinburgh Research Explorer

Document Version:
Peer reviewed version

Published In:
23rd European Conference on Pattern Languages of Programs (EuroPLoP '18)

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Abstract

In a straightforward meta-level shift of focus, we use design patterns as a medium and process for capturing insight about the process of design. We survey mainstream design genres, and draw conclusions about how they can help inform the design of intelligent systems.

CCS Concepts

• Computing methodologies → Knowledge representation and reasoning; **• Software and its engineering → Patterns**; **• Human-centered computing →** *Collaborative interaction*;

Keywords

Design Processes, Design Patterns, Conceptual Blending, Artificial Intelligence, Human-Centered Artificial Intelligence, Creativity

ACM Reference Format:
Joseph Corneli, Simon Holland, Alison Pease, Paul Mulholland, Dave Murray-Rust, Theodore Scaltsas, and Alan Smaill. 2018. Patterns of Design. In *23rd European Conference on Pattern Languages of Programs (EuroPLoP '18), July 4–8, 2018, Irsee, Germany*. ACM, New York, NY, USA, 11 pages. https://doi.org/10.1145/3282308.3282331

Introduction

What is design, and why does it matter? The word derives from the Latin verb for marking (*dēsignō*). The etymological perspective tells us that design is linked with designation, and, more fundamentally, with significance. Etymology also shows us that design is close to 'programming', which comes from the ancient Greek word for a written public notice or edict (Figure 1). Knox [45] describes the modern evolution of the meaning of 'design', which has variously denoted:

Figure 1

- "an art of giving form to products for mass production,"
- a practical theory of "planned obsolescence,"
- combinations of "science, technology and rationalism" addressed to "human and environmental problems,"
- surfaces for "the luring of consumers for the purpose of gaining their money,"
- the deeper problem of "designing the consumers themselves."

Johansson-Sköldberg et al. [44] discuss five related contemporary theoretical perspectives on "design and designerly thinking," encompassing the *creation of artefacts*, *reflexive practice*, *problem-solving*, *reasoning and sensemaking*, and *the creation of meaning*. Design may be, by now, the essential discipline needed for survival in the Anthropocene era, in which humanity is at work on a "concrete and discrete project of global immune design" [80, p. 451]. At any rate, it no longer belongs to the "pipe-smoking boffin" or even the "solitary style warrior" [30, p. 2]. In practice "various experts are in constant close co-operation" and indeed "no group covers a wide enough field" [8, p. 20].

Landscape designer Rolf Roscher suggests that 'belief' and 'landscape' are related in two ways:

> The 'specific': where belief is derived from a place. [. . .] The 'transported': where a landscape is created as a metaphor for a set of beliefs. [75, p. 124]

A now-popular account by the UK's Design Council [24] takes on a somewhat similar two-part form. They propose: "In all creative processes a number of possible ideas are created ('divergent thinking') before refining and narrowing down to the best idea ('convergent thinking'), and this can be represented by a diamond shape." They then suggest that in the process of design, "this happens twice – once to confirm the problem definition and once to create the solution" (Figure 2).

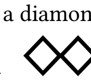


Figure 2

EuroPLoP '18, July 4–8, 2018, Irsee, Germany

ACM ISBN 978-1-4503-6387-7/18/07…$15.00
https://doi.org/10.1145/3282308.3282331

Section 1:	Design Patterns *Decision support for complex situations*	Learning Design *Strategies for learning while doing*	Business Design *Innovations that have a chance of succeeding in the marketplace*
Section 2:	Research Design *Developing a worthwhile problem to work on*	Concept Design *New ways to think about things*	Product Design *Address problems using prior knowledge and common sense*
Section 3:	Experience Design *Transformations of participants*	Knowledge Base Design *Strategies for making "meaning" available to computers*	Designing Intelligence *Strategies for building intelligent systems*

Table 1: Primary Contents: A survey of mainstream design genres.

Accordingly, the Design Council describes the overall process in terms of four phases: *discovery*, *definition*, *development* and *delivery*. Other divisions are possible. Tim Brown [12], one of the chief proponents of "design thinking," describes design in terms of three "spaces"—*inspiration*, *ideation*, and *implementation*—noting that "Projects will loop back through these spaces – particularly the first two – more than once as ideas are refined and new directions taken" (p. 89). Some design thinking acolytes translate this into a more methodical process, based on the six steps *empathize*, *define*, *ideate*, *prototype*, *test*, and *implement*, with additional feedback loops as appropriate. Peffers et al. [72] present a somewhat similar six-phase model; Vaishnavi and Kuechler [86, p. 130] use five phases, and give detailed design patterns that are relevant at each phase. Nessler [65] divides the Design Council's double diamond into no fewer than sixteen sub-phases, and Mann [56] points out that design is often a highly iterative process so that the basic diamond shape could be repeated many times on the way to an ideal solution.

In the design patterns literature, individual patterns are models for specific design processes, and pattern languages are models of more complex design processes with moving, optional, parts. Kohls [46, 47] had described design patterns as being like a journey or route map, but in light of the remarks above they can also be understood in a more ecological way. Moran [63, p. 131] had already remarked, "From the point of view of methodology, it is not so important how good each pattern is, but only that each one is transparent and open to criticism and can be improved over time." Design patterns emerge from an interaction between interpretation and application. The terrain is shaped by patterned behaviour.

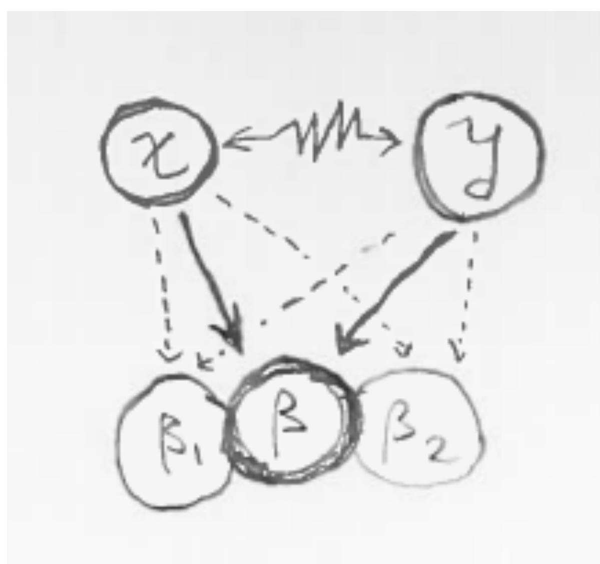
By analogy with solution-oriented phases of design work—where machine intelligence is employed in Computer Aided Drafting (CAD) [50], procedural architecture [70], etc.—we think that technological support could make a big difference to conceptual aspects of problem-oriented work. Several recognised technical efforts notwithstanding, many teams continue to do early-stage design with simple, flexible, analogue tools, such as 3M's PostIt Notes, relying on methods that date back to classical dialectic [29, 68]. These tools and methods are useful for the problems to which they are applied—but these simple, useful, familiar ways of working do not readily incorporate computational intelligence. By engaging computational intelligence in the early stages of design, more perspectives could be taken into account, and more complex problems addressed. The benefits must be bootstrapped using both technical and informal means [64, pp. 67–68].

Nevertheless, there is an important caveat. Alexander [2] argued that once we have a well-defined problem, computers can be used for optimisation, but that this was never the core issue in design. Nevertheless, experimental work has applied computers to design problems both autonomously and together with users [18, 19]. "Creative design" is seen as a testbed for cutting edge AI research [51]. Considering the complexity of today's challenges, and the opportunity that widespread distribution of computing power provides, another effort to understand the key concepts of design is called for. We focus on surveying mainstream genres of design, as summarised in Table 1, with a broader theoretical discussion and practical conclusions in Sections 4 and 5 respectively.

1 Patterns in the creative process

We begin with a recursive move: we describe design patterns *using* a design pattern. This first pattern helps show how all of the patterns are variations on a central theme. We make use of a simple design pattern template inspired by the foundational work of Alexander and Poyner [6].

Design Patterns



Assuming You work in a context that has reasonably stable features; in which the wholes have a somewhat modular form; in which documentation can and will be read and used.

If Forces x and y are frequently seen to be in conflict, and the conflict can be resolved better by β than any alternatives ↯ the relation between x, y, and β is not already well understood.

Then Describe the relation as a design pattern, so that it is accessible and its fitness may be judged.

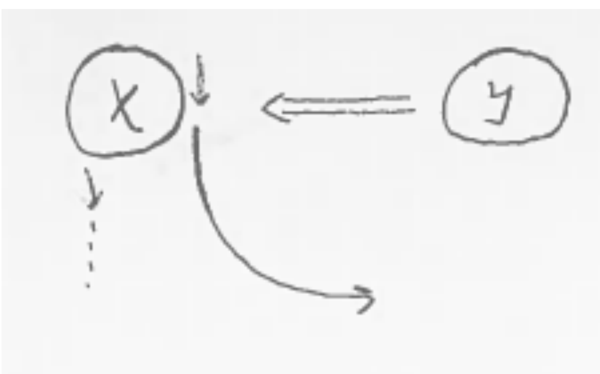
Example This section can serve as a first example of a *design pattern*, and the paper as a whole serves as an example of a *pattern language*.[1]

Alternatives TRIZ is an approach to engineering design centred on common conflicts (e.g., an aeroplane must be both big and light) [84].

Comment. An important implication is that: *whereas design is concerned with the form or structure of objects and processes, the way we think is also structured, and can be shaped by design.* However, design patterns should not be understood as a silver bullet. Alexander reflects, "To caricature this I could say that one of the hallmarks of pattern language architecture, so far, is that there are alcoves all over the place; or that the windows are all different" [36, p. 189]. The way in which patterns are deployed matters. For example, in a programming context, Graham [37] has argued that "regularity in the code is a sign [. . .] that I'm generating by hand the expansions of some macro that I need to write."

Here we have opted to use a pattern template that is simpler than the ones often used in pattern languages for programming. Other fields often have standard templates of their own. We collect examples in Tables 2 and 3, later on below.

Learning Design



Assuming You are working with or within a process that is robust enough to incorporate feedback; there is time and liberty for repeating practice.

If You, or someone you know, needs to keep doing x ↯ continuing to do x unchanged is likely to incur a big cost, or else, there could be a big benefit to changing ↯ change will not be instantaneous.

Then Incorporate suitably-structured feedback into the process to adapt it as it goes.

Example Writers Workshops [31].

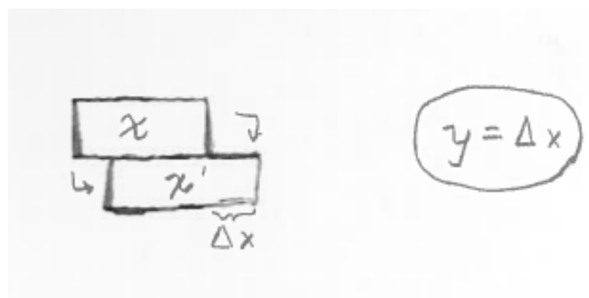
Alternatives *Self-directed* learning tends to integrally involve Research Design.

[1] We use the "↯" symbol to demarcate the conflicting forces in each pattern. Accompanying diagrams are intended to illustrate these conflicts pictorially.

Comment. Learning is said to come in three main varieties: classical conditioning, instrumental conditioning, and skills-based practice (cf., e.g., [20, pp. 160–161]). The questions *who is learning* and *what are their native capacities* are is closely linked with how they learn, and with the corresponding learning designs that are applied. There are often one or more thresholds of response, with different consequences on either side. At a population level, this can lead to stratification.

Watt [88, pp. 7-8] observes that "The way that people learn declarative knowledge (such as facts and rules) is simply different from the way that people learn procedural knowledge (such as skills)." Although some regularities can be observed, learning is not an entirely predictable process, or it would be referred to instead as "control." In pragmatic terms, learning is related to the broader concepts of sociality and co-evolution. Deleuze's [21] remark that "There is no more a method for learning than there is a method for finding treasures" serves to highlight the difference between *design* and *method*.

Business Design



Assuming A new way of doing things (a method) or a new connection between disparate regions (with a corresponding opportunity for arbitrage) opening the way to desirable products or exchanges.

If You know that there is a market for x ↯ You reckon that you can deliver x', which has some differences.

Then Figure out how people perceive x'; be prepared to market x' in a different. way from x, or to adjust the process and produce x'' (etc.) instead

Example Honda could not compete with Harley Davidson in the US, but their Super Cub was fun to ride off-road: they made a niche for dirt bikes.

Alternatives Markets; central planning.

Comment. Designing a business means thinking about a product or service in context. A perfectly good product might not sell if it's marketed the wrong way. A great idea might not be economical if it's produced in the wrong way. According to Ronald Coase, firms come into being when in-house communication is more efficient than market transactions. Simon [78, Chapter 2] contends that the key difference between businesses and markets has to do with the way they process information, namely via hierarchy in the business setting. Businesses may be thought about in systematic or even quasi-organic terms: although they remain somewhat modular, the parts are not strictly interchangeable. Along with supply, demand, competition, and turnover, one of the important parameters is how the business is funded: as with a home mortgage, responsibilities

Pattern Name (Scope, Purpose): Intent: Also Known As: Motivation: Applicability: Structure: Participants: Collaborations: Consequences: Implementation: Sample Code and Usage: Known Uses: Related Patterns: *Gang of Four pattern template*	Course Aims: Course Structure: Learning Outcomes: Assessment Plan and Submission Dates: Timetable: Course Tools and Requirements: Indicative Reading List: *standard course syllabus outline*	Key Partners: Key Activities: Key Resources: Value Propositions: Customer Relationships: Channels: Customer Segments: Cost Structure: Revenue Streams: *Business Model Canvas,* *from Alexander Osterwalder*

Table 2: Sample templates for Design Patterns, Learning Design, **and** Business Design

to funders can come with considerable constraints on future development [36, Chapter XIV]. As software eats the world, "business" may increasingly tend to rely on statistical A/B testing. (Notice as well the similarity to Learning Design: this is in some sense a discretised version of that pattern.)

2 Parameters of design processes

Each of the patterns we present has a number of parameters that can change the way it works in specific instances. For example: *Who is creating the design in question? What are their capacities and constraints? How will the designs be used? How fluid is the overall situation?* In this section, our aim is to outline strategies that address basic questions that will come up time and time again in various design settings. *What is the problem? How might it be addressed?* and *How can the solution be developed?* Given the general nature of these questions, there are many ways to go about generating an answer. These constitute the essential parameters of design.

Research Design

Assuming A knowledge domain that is at least implicitly organised; some liberty of choice to select and explore problems, strategies, and priorities.

If You need something worthwhile to work on. ↯ You don't know in advance what will turn out best. ↯ It might not even be clear what's possible or practical

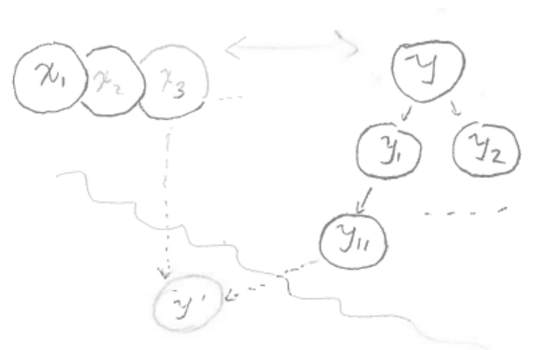
Then This can be tackled at the meta-level—make it personal. Ask how known problems relate to each other through you. What do you need to learn to participate more fully? What's at stake? (Cf. Learning Design, Business Design.)

Example Edward Jenner, inoculated with smallpox as a child (a risky process!), later developed vaccination (safer and more effective) by drawing on local knowledge and careful experiments, subsequently carrying out impactful dissemination.

Alternatives Individual grants are even more about "the person" than standard grants.

Comment. Russell [76, p. 110] suggested that the essential thing is "the substitution of observation and inference for authority." According to Kuhn [48, p. 5] "normal science," makes some compromises *vis à vis* that requirement. Further varieties include "basic", "applied" and "use-inspired" research [83]; another typical division is between research that is "exploratory," "descriptive," or "explanatory" [85].

Product Design



Assuming An at least somewhat decomposable problem; empathy for those affected; previous problem-solving experience.

If You are confronted with a problem y ↯ You have a repertoire of solution strategies x_1, x_2, etc., none of which apply directly to y.

Then "Reverse" the difficult parts of y, one by one, until you find an easier variant of the problem that can be solved using one of your existing strategies. Think about how the solution would be perceived emotionally by those affected, and then adjust the solution based on your assessment.

Example Scaltsas [77] analyses the famous myth of the Trojan horse using this model (Figure 3). *The reversal*: What if Troy was no longer impenetrable: say the Trojans opened the gates? *Emotional assessment*: They would be happy to do this if they were receiving a gift. *The adjustment*: What if the gift disguised a trap? Compare: homelessness might be addressed (symptomatically) by creating small-scale shelters: would the public and users find it acceptable if shelters were built into advertising hoardings [40, p. 59]?

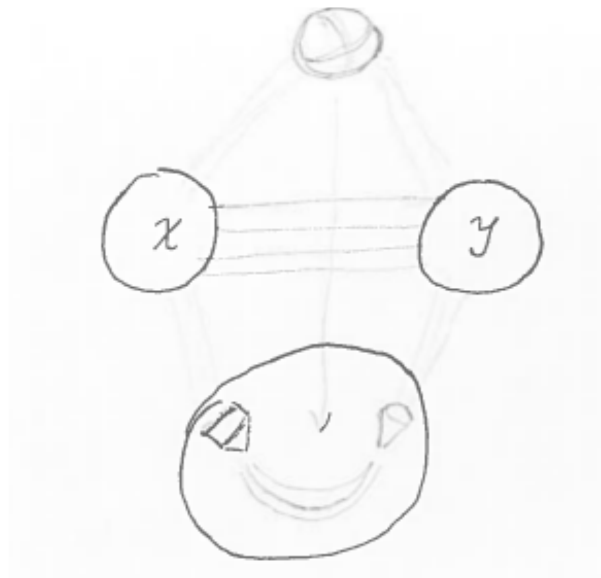
Alternatives TRIZ similarly says to move from a specific problem to a generic one that has a solution. The overall structure of this pattern is also similar to the basic situation in case based reasoning. Something along the lines of anti-unification, which leads to the least-general generalisation, may be relevant to making the reversal step useful.

Comment. Scaltsas's "BrainMining" approach attempts to work with the human tendency to *anchoring bias*, which in the case of a difficult problem can readily result in "stuckness." The same bias might tend to make every problem "look like a nail" relative to existing solution strategies. The emotional assessment phase moderates that tendency. However, if the emotional assessment component ends up dominating, the process could begin to look like "design by committee." The focus on solutions in this pattern could come with a tendency to develop symptomatic treatments rather than etiological understanding.

This pattern could be seen as the mirror image of Research Design, and they can be used together. Whereas that pattern assumed a stock of problems that must be navigated and selected from or added to, this one assumes a stock of existing solution strategies.

Figure 3

Concept Design



Assuming the capacity to think about one thing in terms of another, to find common themes, and to keep a potentially complex array of models in mind; also, a certain background understanding of the way the world works, and some sense of the distinction between fiction and fact.

If you need to think or communicate about x but you don't understand it completely ↯ you understand the phenomenon y reasonably well ↯ x has some abstract features in common with y.

Then form a blended structure β that integrates x and y by first identifying and incorporating their common features; combine additional structure from both sides, possibly recruiting additional extraneous structure to round out the picture.

Example "Thatcher, Thatcher, milk snatcher" blended the then-Secretary of State for Education and Science with a policy whose implementation she oversaw, creating an image at human scale.

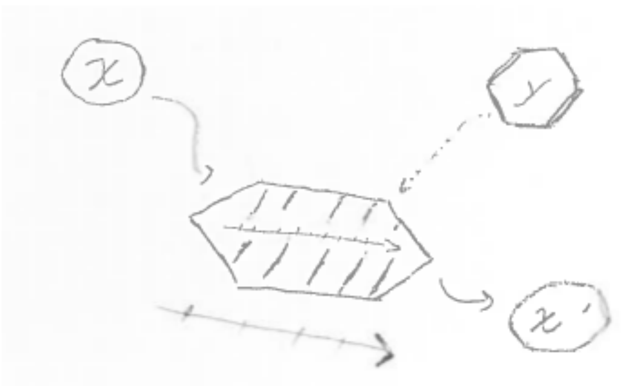
Alternatives With minor changes to the above, two different phenomena, both understood only partially, can be thought about by integrating them together.

Comment. The central goal in concept blending or concept integration, as described by Fauconnier and Turner [28], is to *achieve human scale.* This is similar to the process of making things personal that comprised the core of the solution in Research Design. Blending has influenced our analysis of all of the patterns we present here. This can perhaps be seen most clearly in the accompanying diagrams, each of which presents a different variant on the x, y, β scheme. Whereas Alexander and Poyner [6] focused on resolving contradictions, this takes on further dimensionality in the blending process: first, finding an analogy between the two sides, then finding a context in which they fit together, and, moreover, in which this becomes meaningful. In contrast to the metaphor of "atoms" that Alexander and Poyner used, Fauconnier and Turner [27] write that "the most suitable analog for conceptual integration is not chemical composition but biological evolution." They contrast their model of figurative thought with formal approaches, in which "identity is taken for granted," "analogy [. . .] is typically not even recognized" and in which, accordingly, difference is hard to conceptualise [28, Chapter 1].

3 Relationships with technology

This section presents three patterns with a more speculative feel, ultimately drawing together the themes discussed so far.

Experience Design



Assuming organisation of activity is to be maintained over time, or created anew; emotions can be aroused and senses engaged.

If new whole persons must be created ↯ relevant experience is not immediately accessible or likely to happen on its own.

Then Build experiences that shape the person, so that they enact patterns of structure, order, hierarchy, and category—or their opposites, chaos, play, unpredictability—as well as associated contrasts such as in/out, reveal/conceal, inversion/reversion. If the experience should result in transformation, resolve contradictions between who the person is and who they must become, using significant lived symbolism. The experiences should be immersive: time may pass differently for those engaged in them; in the extreme it may be as if an entire lifetime had passed.

Example In the pattern *Entrance Transition*, Alexander et al. describe a building entrance as a place to shed the persona associated with the street (Figure 4). "The experience of entering a building influences the way you feel inside the building. If the transition is too abrupt there is no feeling of arrival, and the inside of the building fails to be a sanctum" [5, p. 594]. Elsewhere, Alexander remarks that "The buildings that I build very often have a dreamlike reality. I don't mean by that they have a fantasy quality at all, in fact quite the reverse. They contain in some degree the ingredients that give dreams their power" [9].

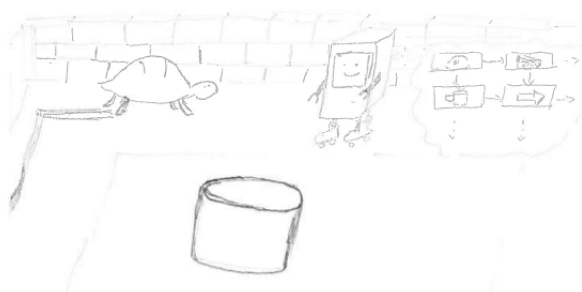
Alternatives Handelman [38] gives a typology of "public events" and a thorough analysis that inspires this pattern. In particular, *events that present* are juxtaposed with *events that model*. The former "are mirrors held up to social order, reflecting and expressing the compositions that their composers desire for society" (p. xxix). An event of the latter sort "generates

Figure 4

and produces controlled change within itself, change which has a directed and direct effect on the world beyond the event" (pp. xxi–xxii). He also describes a third variety, *events that re-present*, which "do work of comparison and contrast in relation to social realities [. . .] by offering propositions and counter-propositions, within itself, about the nature of these realities" (p. 49).

Comment. In typical usage, "experience design" would imply *user experience design*. Human beings tend to be able to make sense of phenomena such as being distinctly separate yet intimately related [38, pp. 155–156] which would presumably fail to register for current machines. Notice as well that despite the power of conceptual blending as described in Concept Design, it doesn't directly explain which concepts will be experienced as significant.

Knowledge Base Design



Assuming Some agent who must navigate an unfamiliar space.

If the agent needs to make sense of possible behaviours in this space ↯ the agent has their own background of meaningful behaviours in some other space.

Then form bridges between the two ways of thinking, e.g., by making the goals and beliefs that apply in the new space explicit.

Example Two paradigmatic examples are depicted in the image above. The first is the Logo turtle, a virtual robot that followed instructions written in the Logo language, originally developed by Seymour Papert, to run on a custom computer

Who benefits, and how do they benefit:
Description for a general audience:
Track record:
Objectives & Methods:
Research Programme:
Project Gantt Chart:
Justification Of Resources:
Pathways To Impact
(Knowledge, People, Society, Economy):
Academic beneficiaries:
National importance:
"Standard Research" from the Engineering and Physical Sciences Research Council

Compress what is diffuse.
Obtain global insight.
Strengthen vital relations.
Come up with a story.
Go from Many to One.
Sub-goals of blending, from Fauconnier and Turner

Theory of evaluation:
utility theory, statistical decision theory
Computational methods:
choosing optimal alternatives
for choosing satisfactory alternatives
The formal logic of design:
imperative and declarative logics
Heuristic search:
factorization and means-ends analysis
Allocation of resources for search:
Theory of structure and design organization:
hierarchic systems
Representation of design problems:
Social design:
Bounded rationality
Data for planning
Identifying the client
Organizations
Time and space horizons
Designing without final goals
Curriculum for design from Herbert Simon

Table 3: Sample templates for Research Design**,** Concept Design**, and** Designing Intelligence

for educational use designed by Marvin Minsky [11]. Physical turtle robots had been developed previously, typically with sensors. In standard Logo implementations, there were no sensors, and moreover, the turtle did not have access to a global coordinate system: it follows strictly local instructions, step-by-step [34]. (Subsequent work with StarLogo expanded upon these basic features [74].) The other example comes from another educational program, ChipWits, released in 1984. The eponymous *ChipWits* are virtual robots that "inhabit maze-like worlds of connected rooms, each filled with an odd assortment of junk" [7]. Unlike the Logo turtle, these robots have sensors, which they can use to detect useful items and avoid threats. In addition, rather than being programmed in a restricted dialect of LISP, ChipWits are programmed in an Icon Based Operating Language, hooking actions together on circuit boards (Figure 5). The visual language makes it more clear that alongside the maze-like worlds, there is an abstract space of possible programs for navigating these worlds. This seems to help the programmer identify with the agents' mental states [88]. A natural evolution of ChipWits would add facilities for meta-programming, whereby simulated robots could self-program by interacting with their environments. Devlin et al. [25] tackle a similar problem using examples and code synthesis; DeepMind's breakthroughs in videogame-playing used self-programming with non-symbolic representations (i.e., pixel-level inputs and neural networks) [61].

Alternatives Word co-occurrence and ordering are two ways by which meanings are transmitted in language [39], using associations which have developed over time [20, pp. 63–64]. Contemporary computational models often exploit this property. For instance, McGregor [59] uses a geometric approach to build models that locate sub-categories within categories, in such a way that projections onto lower dimensional subspaces reveal the salient relationships between terms. Thus, predators and pets, as well as canines and felines, are found within the category of animals; in one subspace "wolf" and "lion" are nearby, in another, "wolf" and "dog" are nearby (pp. 38–39). Character-level analyses have the advantage that they do not require prior knowledge of the language [73].

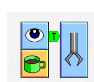
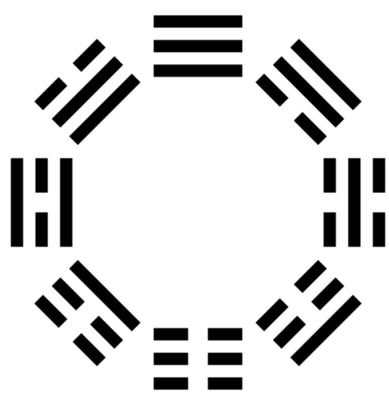


Figure 5

Comment. Simon [78, p. 111] says that "Everyone designs who devises courses of action aimed at changing existing situations into preferred ones." Clearly, some representation of the state of world is a prerequisite. Simon considers memory as external to the agent.

Designing Intelligence



Assuming a notion of "intelligence" that is recognisable to humans.

If designing a system where intelligence is needed, of whatever form or scale ↯ which cannot be abstract but must be embodied in some social, physical, or software system.

Then Notice when the patterns we have described are blocked, so that, e.g., learning doesn't happen, businesses stagnate or crumble, research is ineffective, products are not useful, concepts are unclear, experiences are not meaningful, the world is incomprehensible. This can suggest conflicts around which new Design Patterns can be created, or hint at how existing patterns can be refined.

Example Marvin Minsky's [60] *Society of Mind* presents a high-level design in which the small component systems—agents—contribute different aspects to the system as a whole. His core rubric is: "Each mental agent by itself can only do some simple thing that needs no mind or thought at all" (p. 17).

Alternatives The patterns we have presented point out some directions in what is clearly a vast possibility space. According to Alexander [3, p. 10] what is essential is to "build on the structure that is there, do not destroy it or interfere with it, but rather enhance it and elaborate it and deepen it," in contribution to a larger whole. Consider that animal and even vegetable intelligences can learn [32], and, moreover, engage in niche creation.

Comment. Andy Clark [16] remarks on the special form this takes for humans:

> "Against the enabling backdrop of the homeostatic machinery that keeps us within our windows of organismic viability, the shape and contents of the rest of our mental lives are determined by prediction-driven learning as it unfolds in the ecologically unique context of our many designer environments [. . .] that enforce exploration and novelty-seeking in ways hitherto unknown among terrestrial animals."

Good [35] sketches a neural model comprised of relatively stable assemblies and more frenetic subassemblies, closer to the senses, which seems analogous to the above: "If assemblies correspond to conscious thoughts, it might well be that subassemblies correspond to unconscious and especially to preconscious thoughts" (p. 58).

4 Discussion

Galle [33] meditates on design patterns as potential "atoms of conceptual structure." He notes that, with few exceptions—such as Moran's classic proposal for an "Architect's Adviser"—design patterns were ignored in the knowledge-based systems literature. Many of the historically-early support tools emphasised the physical properties of objects and their combinations.

With this in mind, we can contrast *conceptual design*, as we understand this term, with the perspectives on "making" advanced by Ingold [42]. Ingold follows Deleuze and Guattari [22, p. 408] in highlighting interactions between maker and medium, e.g., "surrendering to the wood, and following where it leads." This example is cited in opposition to simplified narratives of form-giving considered as a "technical operation which imposes a form on a passive and unspecified matter" [79]. The passive and active processes might be diagrammed as follows:

$$\frac{\textit{clay}}{\textit{brick}}\,\text{form} \qquad\qquad \frac{\textit{axe}\quad\textit{wood}}{\textit{split wood}}\,\text{technique}$$

A clue that these authors are not actually refuting "hylomorphism" in the way they claim comes directly from the choice of examples, and the fact that *húlē* originally means wood. In any case, Ingold's broader concern is with theories and thinking that he deems to be insufficiently aware of process, including applications of causal thinking to situations which are more complex. He makes the case that co-evolution is more widespread than we tend to acknowledge. Following Alexander and Poyner [6, p. 318], let us fly right into the heart of the debate with another diagram rather like the two above:

$$\frac{\textit{if}}{\textit{then}}\,\text{because}$$

The associated issues seem to become clearer if, instead of "because," we understand "assuming," as per our usage in the foregoing sections. In design patterns, the links between "if" and "then" seem to depend on complex articulations, not on single causes. Consider these examples, adapted from Aristotle (*Physics*, Book II, Part 9):

- *If* you want to make a house, *then* you need a roof, *assuming* the house is for humans on open ground.
- *If* you want to make a saw, *then* use hard material for the blade, *assuming* the saw is driven by hand-power.

When phrased this way, it is as if we have been explicitly invited to think of exceptions to the rule. Moreover, when the exceptions have something in common, they can be captured in design patterns. Consider:

- Both a *sheep pen* and a *cave dwelling* do not need a roof because they *Reuse A Natural Covering*.
- Both a *water jet cutter* and a *plasma cutter* can *Have The Power Source Do The Hard Work*.

From a design perspective there will be further exceptions, e.g., a sheep's wool can protect it against rain, not against predators; a plasma cutter can only cut conductive materials, and so on.

Simon [78] described "goals" as the interface between internal and external organisation, and something similar is going on in the diagrams above. Goal structure, whether situated in form, technique, cause, or articulation through reasoning or embodied action, relates systems' internal and external structure. This helps explain why the brick-making and wood-splitting scenarios feel different. The grasp of the hands on the axe handle is intimately related to the mind's grasp on the chop. Part of the goal structure of the activity of chopping wood has been solidified in the shape of the axe itself. However this is not fully determining: the axe could, under different circumstances, be used as a weapon [20, p. 72–74]. More broadly,

> "The existence of top-down causality implies that the evolution of any given assemblage will be partly autonomous and partly influenced by the environment created by the larger assemblage of which it is a part" (*ibid.*).

DeLanda points out that the term *assemblage*

> [. . .] fails to capture the meaning of the original *agencement*, a term that refers to the action of matching or fitting together a set of components (*agencer*),

> as well as to the result of such an action: an ensemble of parts that mesh together well. (*ibid.*, p. 1)

This notion of an evolving "*agencement*" nicely characterises the status of the proto-patterns *Reuse A Natural Covering* and *Have The Power Source Do The Hard Work*. In contrast to the brick-making and wood-cutting examples, these two example proto-patterns are *creative*, insofar as they involve concepts "not present in [the] statement of the problem and the general knowledge surrounding it" [57]. Let's consider this more deeply.

Smith [81] describes *concepts*, as they are treated within Deleuze's analytics, as existing in a state of becoming that requires both self-consistency and internal variability. Moreover, new concepts only arise when we are forced to think! Alexander and Poyner [6] say something quite similar: *design* is only needed when there is a conflict between tendencies that cannot be resolved in a more direct way. Nevertheless, where could new concepts possibly come from if not some broader or restructured context surrounding the problem? For instance, one class of inventions could be accounted for in terms of Simondon's notion of *autocorrelation*, which is involved in the literal *Reinvention of the Wheel* as built around a hub that contains free-rolling ball bearings [15, pp. 10-11]. Another distinct option would be to go on a journey and collect new material (Figure 6). The journey metaphor is preferred by Kohls in his model of design patterns [46, 47]. Notice that with a long-enough journey, it may be natural for the set of assumptions themselves to change, hinting at something akin to Peircean abduction [26]. Combinations of the two pattern-schemas recover Alexander's abstract model of "harmony" [3, p. 38].

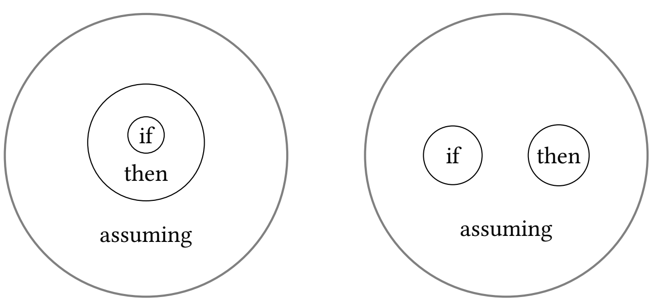


Figure 6: Two different pattern-schemas

Elsewhere, Alexander [1, p. 134] observed a distinct meta-level phenomenon that is similar to autocorrelation, namely the "structural correspondence between the pattern of a problem and the process of designing a physical form which answers that problem."

As always, the precise details depend on context—and also on how "context" is understood. Surveying developments in 18th and 19th Century science, Georges Canguilhem [13] pointed out that:

> With the success of the term *milieu* [over the related notions of *circumstances* and *ambience*] the representation of an indefinitely extendible line or plane, at once continuous and homogeneous, and with neither definite shape nor privileged position, prevailed over the representation of a sphere or circle, which are qualitatively defined forms, and, dare we say, attached to a fixed center of reference." (Translation in [14].)

Both Alexander and Deleuze have sought to recover certain circumstantial and vital aspects of being, without descending wholesale into vitalism (*viz.*, the belief that "living organisms are fundamentally different from non-living entities *because they contain some non-physical element or are governed by different principles than are inanimate things*" [10], emphasis added). In fact, both authors take the concept of "life" and extend it to the inorganic [4, 23]. Ingold [41] discusses a related perspective. "Creativity" is the essence of this leap. Here, we have traced connections between creativity and conceptual design, with examples, leading to the following:

5 Conclusions

Artificial intelligence pioneer John McCarthy [58] wrote: "The key to reaching human-level AI is making systems that operate successfully in the common sense informatic situation." Conceptual design, e.g., via developing pattern catalogues, offers opportunities for feedback and evolution of a humanistic, social, approach to *Intelligence Augmentation*—and, perhaps eventually to Artificial Intelligence as McCarthy described.

The linked problems of representing design knowledge so that it is useful for collaborative design in distributed communities, or usable at all by artificially intelligent computer systems—though of longstanding interest [87]—still needs further effort. Experiments like Oxman's Think-Maps [69, 71] and other examples surveyed by Galle [33] have the air of being technical demonstrations, and are not in widespread use. Pattern repositories like the one described by Inventado and Scupelli [43] do not make significantly more intensive use of computer technology than the Portland Pattern Repository which was hosted on the world's first wiki. The usefulness, for common sense reasoning purposes, of logic-based representations has been debated [62, 66]: evidence suggests that there is always more to the picture. For example, technologies based on the conceptual graphs of Sowa [82], deployed in architectures inspired by the society of mind, have seen industrial use [55], while associated efforts to automate natural language understanding are still ongoing [49, 52, 54]. Fauconnier and Turner [28, p. 109–110] suggest that complex mental phenomena like blending should be studied with human data not simulations.

"Crowd creativity" manages to integrate many of these themes. Here, designs are produced by an evolutionary process with humans in the loop [53, 67, 89, 90]. However, current workflows miss a reflexive component. Design patterns could usefully be incorporated into these processes, to serve as "a living language" that supports design and guides reflection [5, p. xvii]. Corneli et al. [17] outlined one approach for evolving design patterns in a collaboration. Future work could make use of more sophisticated ways to integrate feedback in "biomechanical" [35, p. 34] social systems. The expected outcome would be that citizens would be able to more fully engage with processes that matter. This is just one of many possible designs that these patterns could inform (Figure 7).

Acknowledgements

We are grateful to our shepherd for EuroPLoP 2018, Andreas Rüping, and to the participants in Writers Workshop F: their engagement with the paper led to many improvements. Corneli was supported by the EPSRC (EP/N014758/1, "The Integration and Interaction of Multiple Mathematical Reasoning Processes").

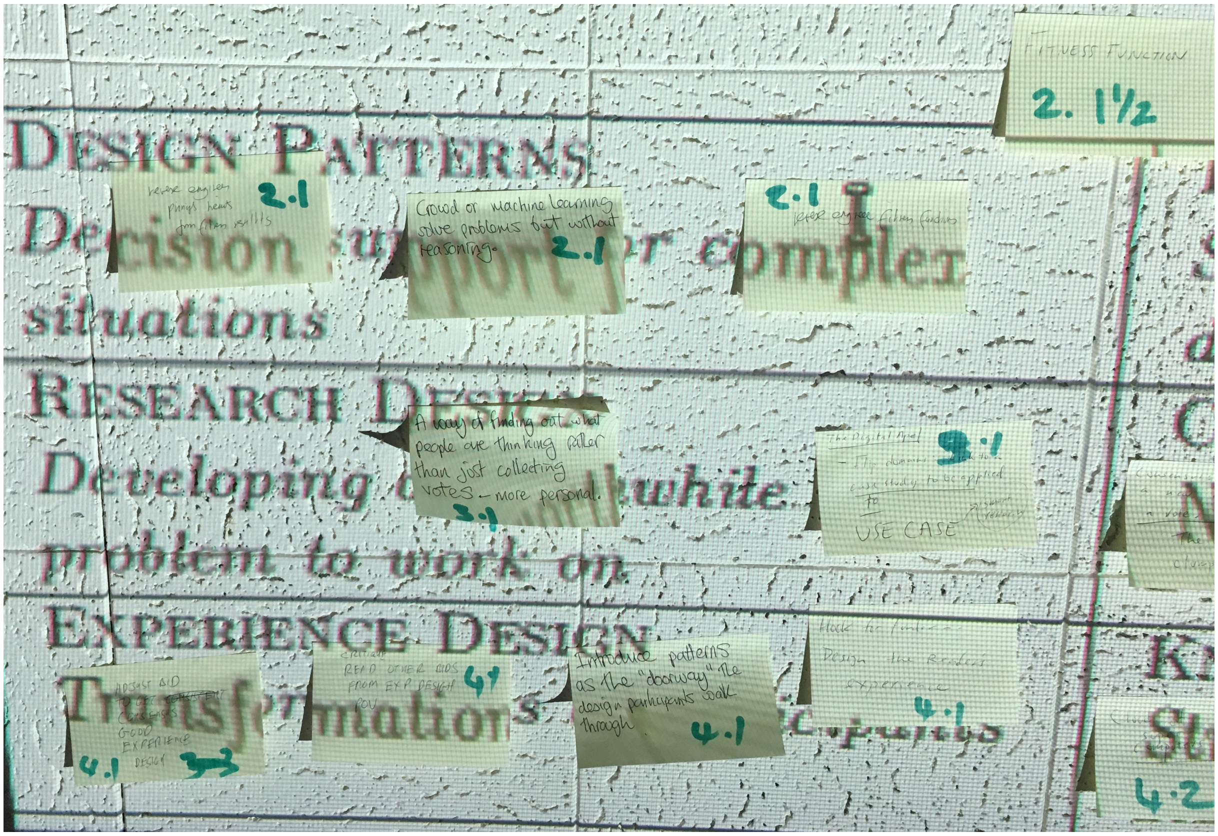


Figure 7: A practical exercise in which we used PostIt notes and a projection of Table 1 to design a research project

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